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Research Report

Research Project NM 11 02 11 Subtask 1 | Report No. 1

A STUDY OF EARLY GREYOUT THRESHOLD AS AN INDICATOR OF HUMAN TOLERANCE TO POSITIVE RADIAL ACCELERATORY FORCE

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Bureau of Medicine and Surgery
Research Project NM 11 02 11 Subtask 1
Report No. 1

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SUMMARY PAGE

THE PROBLEM

The purpose of this study was to investigate the relationship under increased positive radial acceleratory force between peripheral light loss and blackout or unconsciousness when the light stimulus is located at 80 degrees in the peripheral field; and to determine whether an 80 degree peripheral light stimulus was an earlier indicator than lights located at 23 degrees in the peripheral field.

THE FINDINGS

Under conditions of our experiment, it was found that an 80 degree light stimulus was an earlier indicator than the 23 degree light for an endpoint of greyout in regard to magnitude of the G force. The time spread between onset of greyout (80 degree light loss) and onset of blackout or unconsciousness was determined, and this time spread was found to be slightly increased when compared to the use of a 23 degree light as an endpoint of greyout. The peripheral light loss has limited usefulness as an early indicator for the onset of critical symptoms of blackout or unconsciousness.

INTRODUCTION

The development of visual symptoms is frequently used by pilots as an early indicator of the development of unconsciousness at critical levels of positive radial acceleration. These symptoms are well known to pilots and to subjects employed in centrifuge experiments. Heretofore at Pensacola the peripheral lights usually extended to 23 degrees in the peripheral visual field.

Cochran et al. presented centrifuge findings on 1000 subjects, and the mean G tolerance for peripheral light loss (using 23 degree light) was 4.1 G, standard deviation plus or minus 0.7 G; mean G tolerance for blackout was 4.7 G, standard deviation plus or minus 0.8 G; mean G tolerance for unconsciousness was 5.4 G, standard deviation plus or minus 0.9 G (1). Lambert has demonstrated that centrifugal forces induce visual symptoms by causing a decrease in arterial pressure at eye level. When the normal arterial pressure is inadequate to overcome the increased effective weight of blood, impairment of circulation and unconsciousness occurs (2). Duane by directly observing the fundus oculi ophthalmoscopically under positive radial G concluded that during positive acceleration, blackout is accompanied by a retinal arteriolar ischemia which suggested that hypoxia of the inner retinal cells was responsible for the phenomena (3,4).

It is the purpose of this study to investigate, by the placing of lights in the visual peripheral fields at 80 degrees, the possibility that the 80 degree light is an earlier indicator than the 23 degree light in regard to magnitude of G and the possibility of increasing and measuring the time spread from peripheral light loss to blackout or unconsciousness. It was believed that this would afford the subject the earliest indication of peripheral light loss, and thus give him the maximum amount of time before the onset of blackout or unconsciousness during a critical positive G run. Normative data were obtained regarding the 80 degree light loss and its relationship to 23 degree light loss, blackout, and unconsciousness.

PROCEDURE

SUBJECTS

In this study only young, adult, males were used. Their ages ranged between 18 and 37 years. All subjects received a thorough physical examination, and had normal peripheral vision. Experienced and inexperienced subjects were selected. Preliminary control runs enabled the inexperienced subjects to become accustomed to the psychomotor task involved under actual dynamic conditions. All subjects were requested to relax and to make no effort to resist the effect of the acceleration other than that necessary to maintain their heads erect.

METHOD

The centrifuge runs were commenced at 3.0 G or lower (control runs), and increased to 3.5 G followed by successive runs of progressively increasing increments of approximately 0.3 G until visual symptoms appeared, i.e., greying, greyout, blackout, and unconsciousness. The peak G plateau was maintained for a duration of 10 seconds on all runs except when unconsciousness developed. This time of peak G plateau was chosen to eliminate fatigue and to allow cardiovascular compensatory mechanisms to become operative. The mean rate of onset of acceleration of the human centrifuge was 0.98 G/second with a range from 0.90 to 1.15 G/second. The centrifuge chamber temperature was maintained at a constant 70°, plus or minus 2° F. The standard dashboard used on the human centrifuge was modified by placing additional peripheral lights 80 degrees on either side of the central light at the same level as the 23 degree lights (Figure 1). The occipital portion of the subject's head was placed firmly against a head rest and the subject was instructed to focus his vision on the center light. The 80 degree lights were within the peripheral fields of vision of all individuals tested under static and dynamic conditions of the introductory runs.

The illumination was furnished by 28 volt bulbs. The light intensity of all lights ranged between 1 to 8 millilamberts. The center light was red. All peripheral lights were green in color. A central observer watched the subject for any gross muscular tensing which might occur during actual runs. The light stimuli were presented by remote control in a randomized fashion, and the centrifuge room was dark during actual runs. The subjects experienced no difficulty in perceiving any of the light stimuli. The psychomotor task was made as simple as possible to avoid confusion on the subject's part. The subjects responded to the light stimuli by pressing a trigger located on the pistol grip handles which were grasped in each hand.

The subject's response to all light stimuli, particularly 80 degree light stimuli, was studied. The subjective light loss is defined as the run when the individual first states that he cannot see a light stimulus. The objective 80 degree light loss was defined as a failure to respond to this light stimulus for 2.0 seconds or longer during the centrifuge run. The subject was requested to make comments about visual dysfunction after each run. The state of blackout was determined objectively to have occurred when there was a failure to respond to the 80 degree lights and central light for 2.0 seconds or longer, and the subject was still capable of responding to the auditory stimulus. Unconsciousness was determined to have occurred if the subject failed to respond to the auditory stimulus as well as all light stimuli. The subject also demonstrated other clinical evidence of unconsciousness such as the head slumping forward or the appearance of mild convulsive seizures as reported by the central observer. The subjects rendered unconscious by centrifugation usually experienced dreams of a pleasant visual nature.

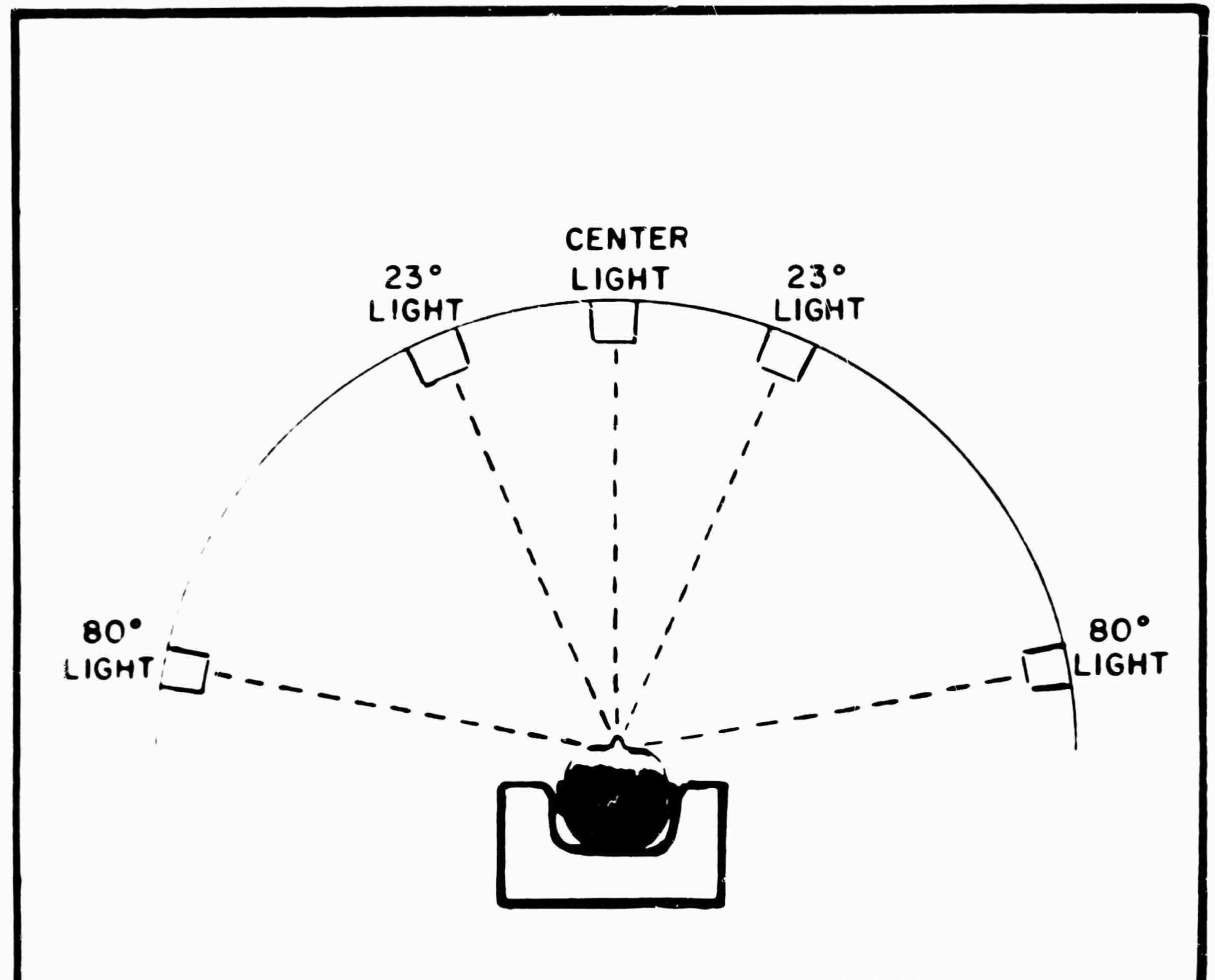


FIGURE I

CENTRIFUGE DASHBOARD PANEL
VIEWED FROM ABOVE

RESULTS

All 115 subjects almost invariably lost the 80 degree light prior to the 23 degree light loss. After completing the experiment it was decided to quantitate this in 30 subjects (52 series), and it was found that the 80 degree light loss occurred at a mean of 4.2 G, standard deviation plus or minus 0.7 G, and in the same subjects the 23 degree light loss occurred at a mean of 4.5 G, standard deviation plus or minus 0.8 G. Table I. This demonstrates also the reliability of the method used since the original 115 subjects and the 30 subjects lost their 80 degree light at 4.24 G and 4.20 G, respectively.

Table I

Comparison of 80° Light Loss with 23° Light Loss

			Symptoms			
	Subjects	Series	Clear	80° LL	23° LL	CLL
Number	30	52				
Mean (G Level)			3.8	4.2	4.5	5.3
Range (G Level)			2.3 - 5.1	2.7 - 5.7	2.9 - 6.4	3.6 - 7.0
Standard Deviation			0.7	0.7	0.8	0.8
Mean Duration of Symptom (Seconds)				5.4	5.1	6.8
Range (Duration of Symptom in Seconds)				1.9-17.0	1.9-11.9	2.1-23.4

The 115 subjects were found to have a mean clear run at 3.8 G. These subjects experienced an 80 degree light loss subjectively at a mean of 4.25 G, standard deviation plus or minus 0.5 G, with a range of 3.5 to 5.2 G. The 80 degree peripheral light loss was recorded on the ink writer at a mean of 4.24 G, standard deviation plus or minus 0.6 G, with a range of 3.2 to 6.2 G. The mode occurred at 4.0 G. (Table II, Figure 2)

"G" VERSUS PER CENT OF 115 SUBJECTS EXPERIENCING 80° LIGHT LOSS

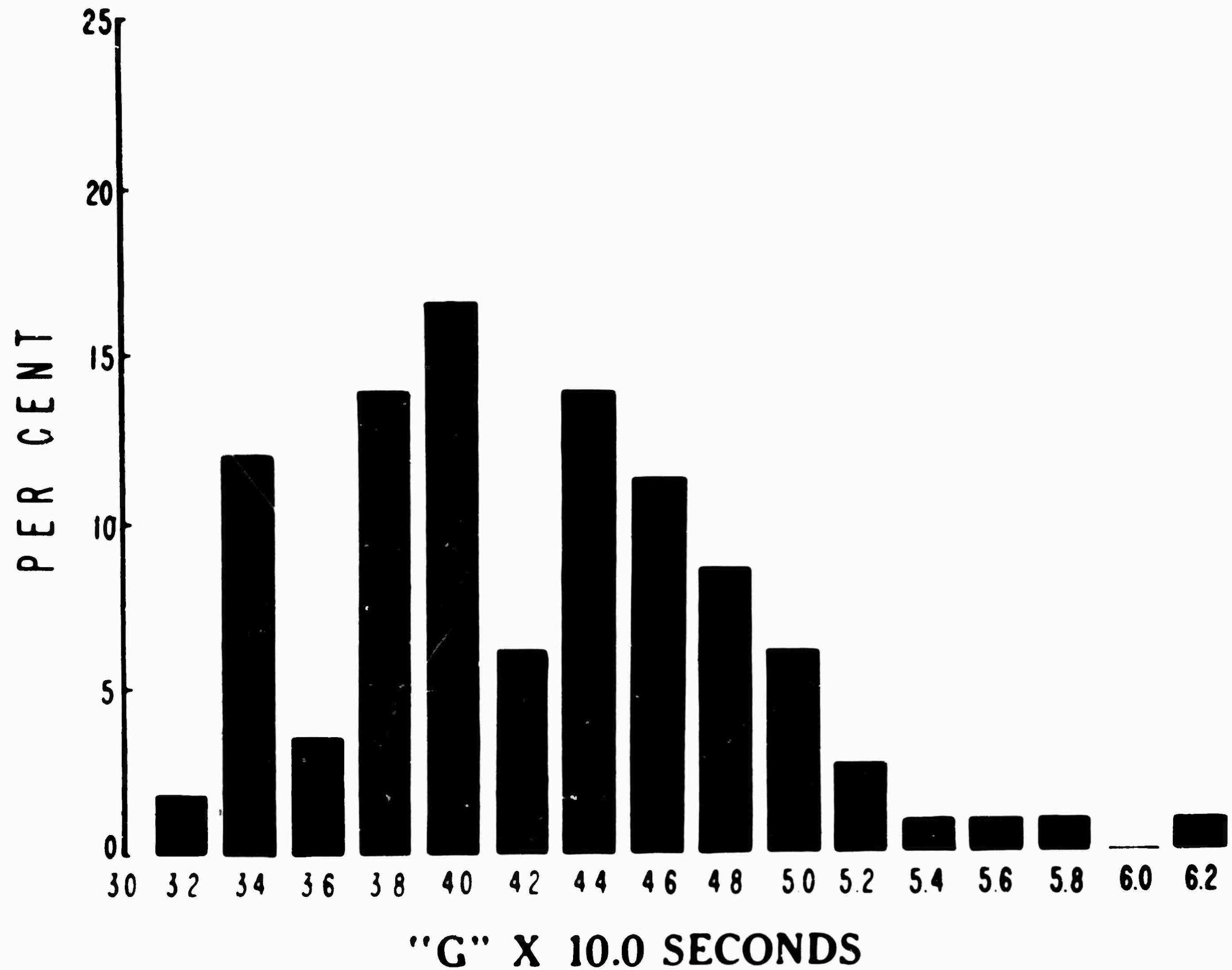


Table II

115 Subjects 80° Light Threshold

	Control Clear	Subjective Light Loss	Objectively Recorded Light Loss
Mean G Level for 10 Seconds	3.8	4.25	4.24
Range (G Level)	2.7 - 5.0	3.5 - 5.2	3.2 - 6.2
Standard Deviation		0.49	0.58
Average Duration of 80 Degree Light Loss (Seconds)			4.4
Range of Duration of 80 Degree Light Loss (Seconds)			2.0 - 15.6
Peak G to Symptom (Seconds)			6.16

In 67 of these 115 cases, the criterion for blackout was clearcut, and the records could be measured accurately. In some of the original 115 subjects taken to 80 degrees light loss, the runs were discontinued because of nausea, vertigo, or other reasons. This total of 67 was divided into three groups:

a) student pilots, N = 27 (inexperienced centrifuge subjects),

b) acceleration personnel who were considered to be an experienced group, N = 20, and

c) others, N = 20 (inexperienced subjects consisting of student flight surgeons, and aviation medical technician students).

The mean blackout level in these 67 subjects was determined to be 4.9 G, standard deviation plus or minus 0.7 G.

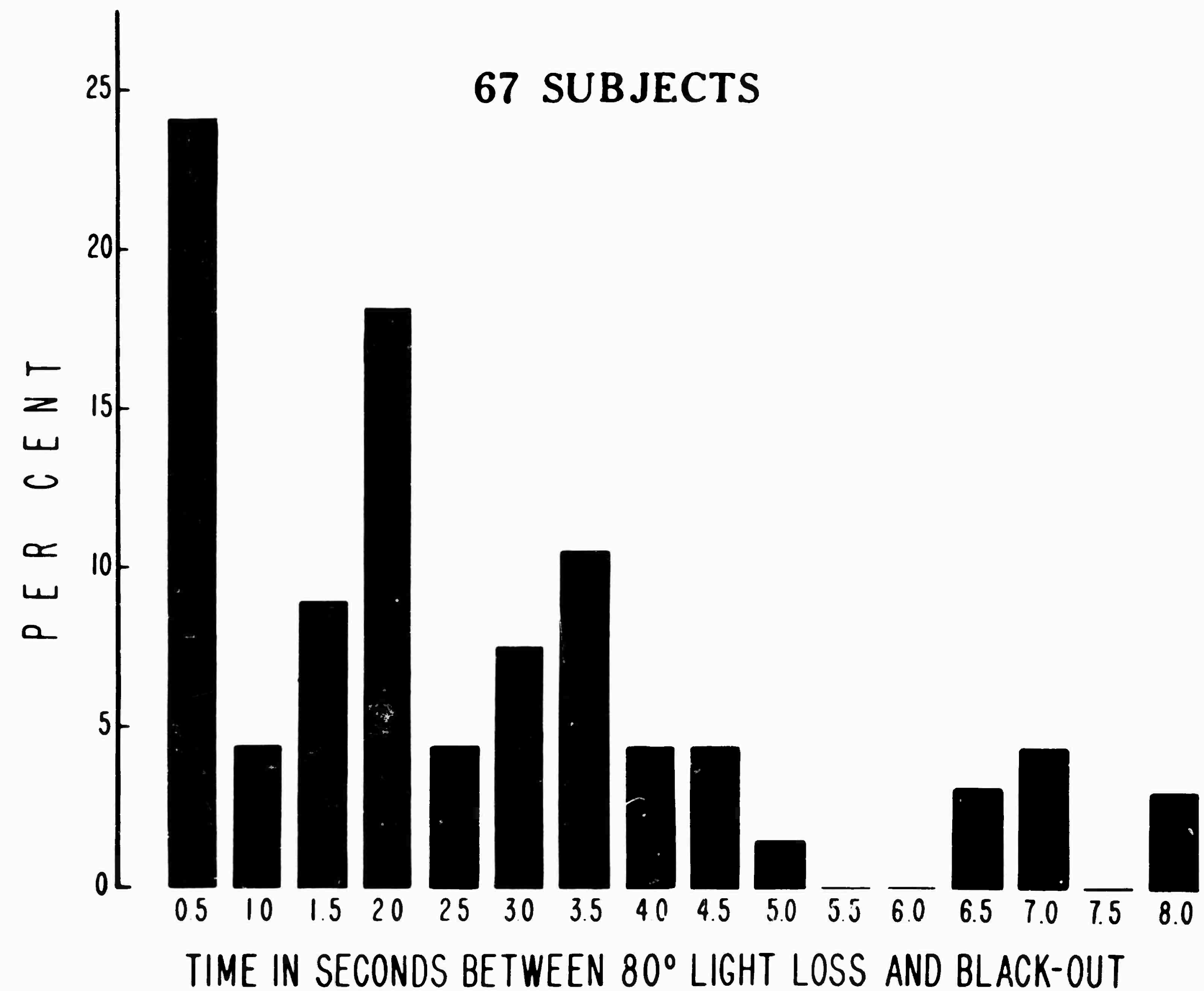
Table III

Maximum Symptom Blackout Peak G was Maintained for 10 Seconds
Relaxed Subjects

Groups	Number of Subjects	G Level 80° Light Loss (Objective)	G Level Blackout	80° Light Loss To Blackout Time (Sec)	Mean Duration of Blackout Time (Seconds)	Mean Onset G/Sec
Total Subjects	115	4.24				0.98
Student Pilots	27	4.39	5.1	2.9	5.94	0.96
Acceleration Personnel	20	4.07	4.65	2.48	4.47	1.12
Others	20	4.43	4.9	3.11	5.84	0.91
Average of the Entire Group of 67 Subjects		4.31	4.9 ($\pm$ 0.7)	2.77	4.3	0.98

From Table III it will be noted that the acceleration personnel (experienced group) developed 80 degree light loss and blackout at lower G levels than our inexperienced groups, and this may be explained by the fact that they may represent more relaxed subjects during centrifugation. The slight difference in mean rate of onset of acceleratory force between the various groups is believed not to be a significant factor. The time spread of the onset of objective 80 degree light loss to onset of objective blackout on centrifugation runs causing blackout only is depicted in Figure 3. The mode occurred at 0.5 seconds, the mean time spread was determined to be 2.77 seconds (Figure 3). The mean time from onset of peak G to onset of the 80 degree light loss was 6.16 seconds. The mean time from onset of peak G to onset of blackout was 7.8 seconds. The range was 4.0 to 12.0 seconds.

PER CENT OF PERSONNEL VS TIME BETWEEN 80° LIGHT LOSS AND BLACK-OUT ON BLACK-OUT RUNS ONLY



The mean G level for unconsciousness in 23 subjects was determined to be 5.1 G, standard deviation plus or minus 0.8 G, range 4.0 to 6.7 G. These subjects were selected at random from the three groups previously described and their numbers are shown in Table IV. The mean time from onset of peak G to onset of unconsciousness was 8.19 seconds; the range was 5.0 to 12.4 seconds. The mean duration from onset of unconsciousness to subject's appropriate response to his environment was 13.9 seconds. The implication of this interval in high performance aircraft is obvious. These data were divided, analyzed, and are depicted in Table IV. The time spread between onset of the 80 degree light loss to onset of unconsciousness is depicted in Figure 4. The mode occurred at 2.0 seconds. The mean was 3.6 seconds. The range was 1.5 to 8.5 seconds.

The time spread between onset of 80 degree light loss to blackout on unconscious runs only is depicted in Figure 5. The mean was 1.77 seconds. The mode occurred at 0.5 seconds.

The time spread between onset of blackout and onset of unconsciousness is depicted in Figure 6. The mode was found to occur at 1.5 seconds and the mean at 1.83 seconds.

DISCUSSION

The effects of retinal dysfunction are related to the subject's vascular reflex capabilities when subjected to the hypotensive effect of centrifugation. These symptoms are a measure of compensatory vascular response (carotid sinus mechanism, tachycardia, vasoconstriction) mediated through activity of the autonomic nervous system.

Under the procedure employed in this experiment only 33.9 per cent of the 115 subjects experienced a dimming of the 80 degree light prior to obtaining an 80 degree light loss. The mean G levels between the subjective and objectively recorded 80 degree light loss were statistically insignificant. In our series the mean G spread from 80 degree light loss to unconsciousness was determined to be only 0.9 G and that the G spread between blackout and unconsciousness is extremely small.

The mean symptom latent period to onset of 80 degree light loss was determined to be 6.16 seconds after the peak G plateau was obtained. Of the group of 67 subjects (Table III), the student pilots seemed, in general, to have a slightly higher G tolerance for the development of blackout and unconsciousness (Table IV). The mean time from

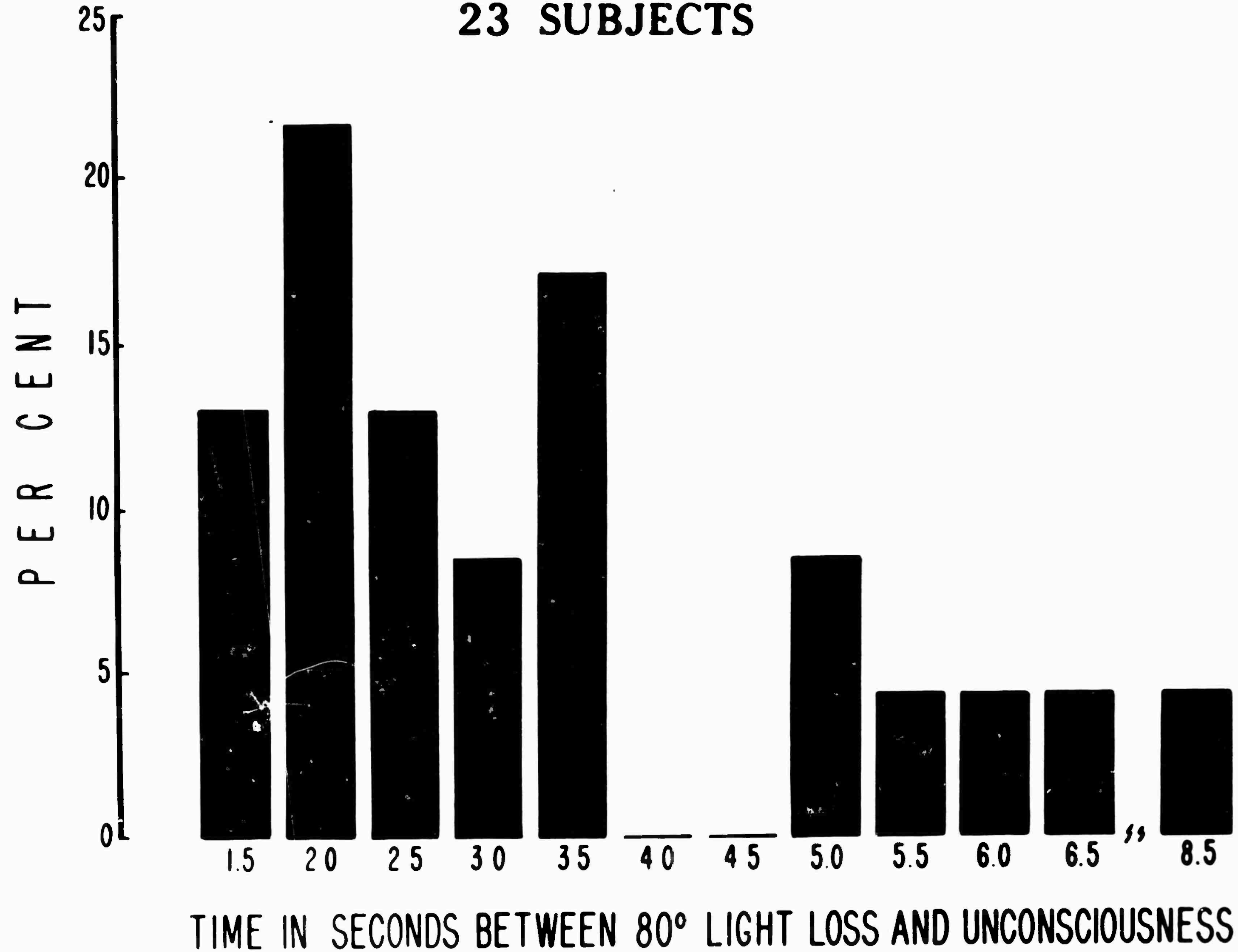
Table IV

Maximum Objective Symptom Unconsciousness - Relaxed Subjects (All runs 10 Seconds or Less)

		Mean G Level					
Groups	Number Subjects	80° Light Loss Objective	Unconscious	80° Light Loss To Blackout Time (Sec.)	Blackout To Unconscious (Seconds)	80° Light Loss To Unconscious (Seconds)	Duration To Unconsciousness (Seconds)
Total Subjects	115	4.24					
Student Pilots	10	4.42	5.45	1.47	1.32	2.79	17.53
Others	7	3.92	4.46	1.42	1.37	3.69	10.11
Acceleration Personnel	6	4.2	5.26	2.68	2.17	4.85	12.4
Average	23	4.22	5.1 (± 0.8)	1.77	1.83	3.60	13.93

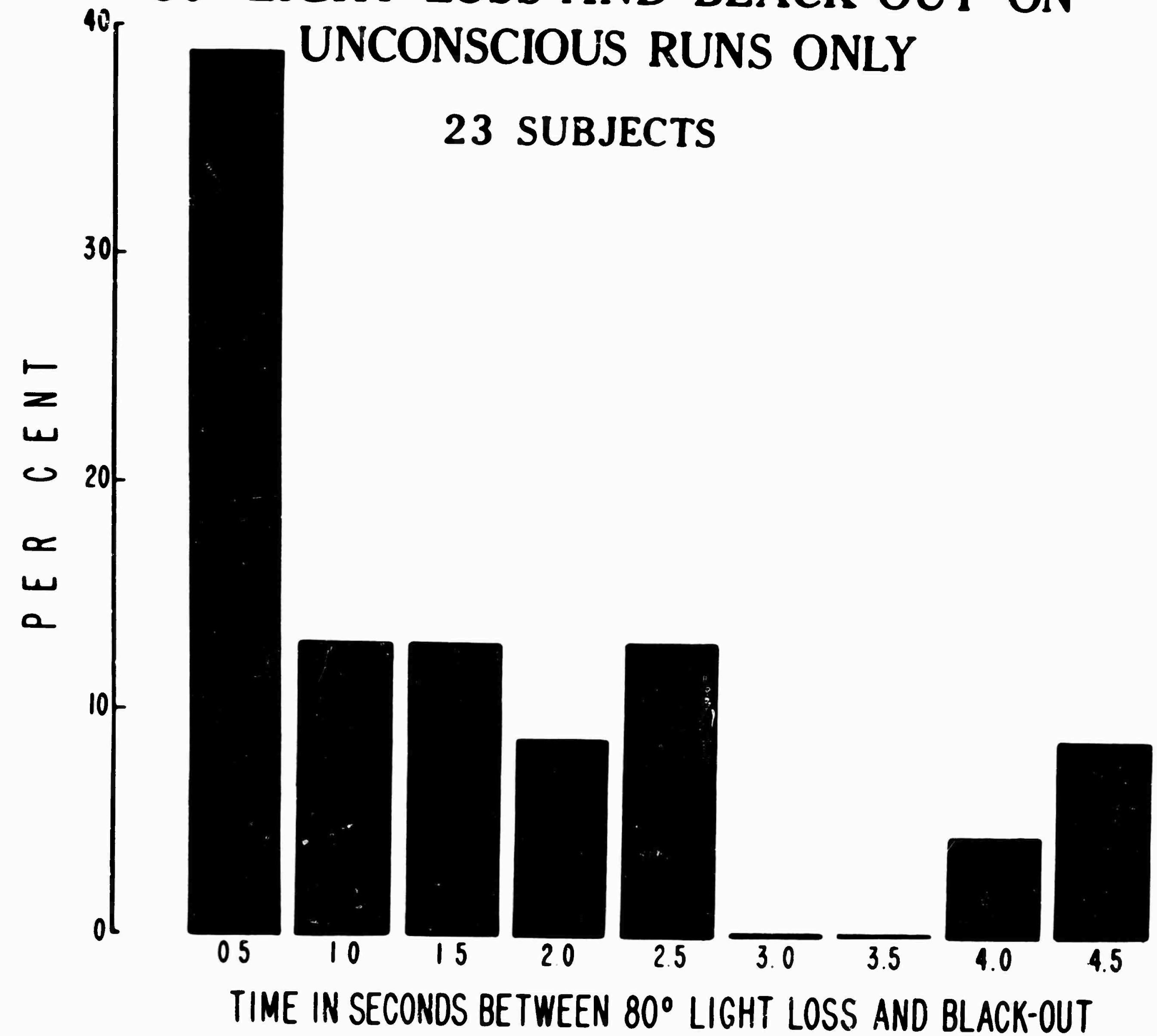
PER CENT OF PERSONNEL VS TIME BETWEEN 80° LIGHT LOSS AND UNCONSCIOUSNESS

23 SUBJECTS

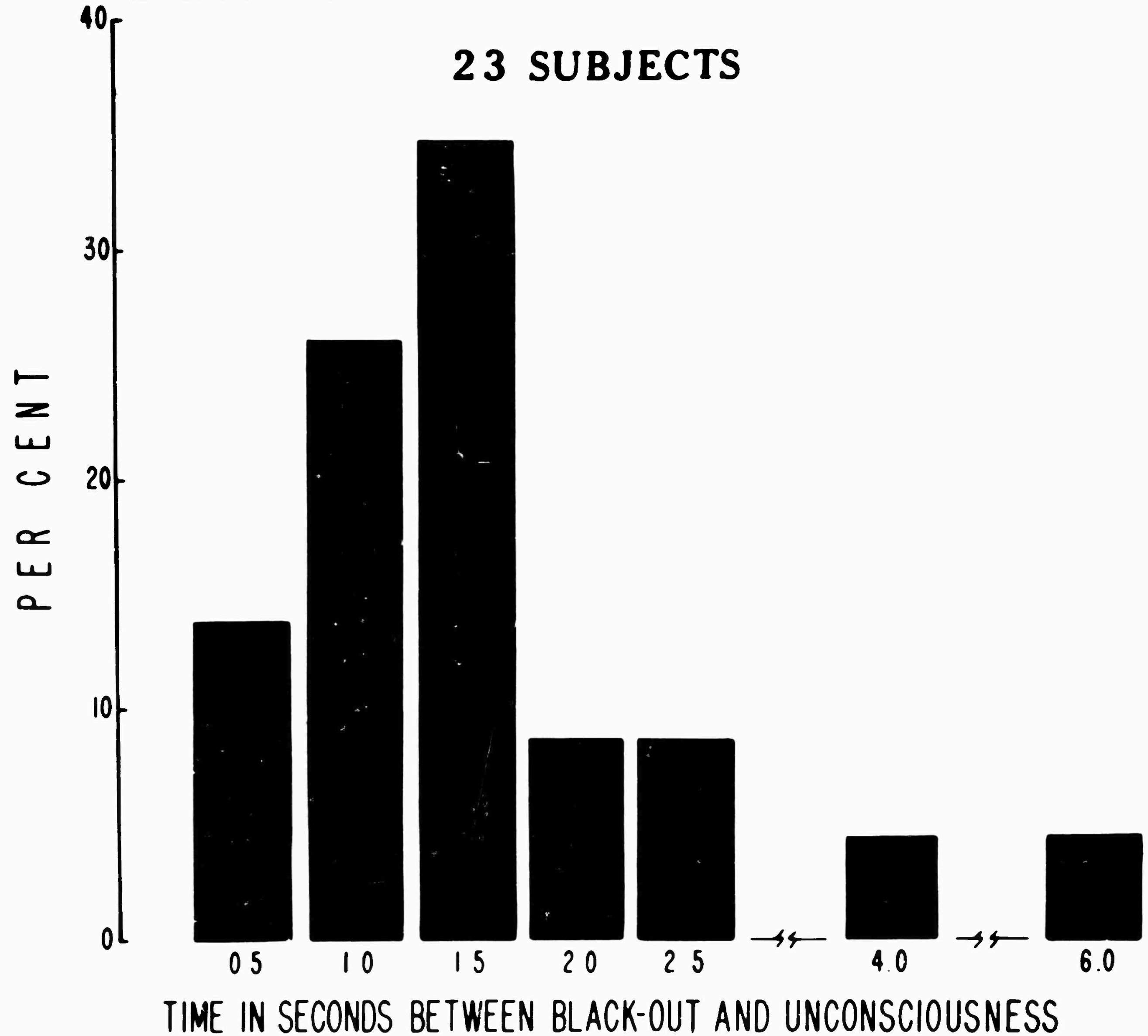


PER CENT OF PERSONNEL VS TIME BETWEEN 80° LIGHT LOSS AND BLACK-OUT ON UNCONSCIOUS RUNS ONLY

23 SUBJECTS



PER CENT OF PERSONNEL VS TIME BETWEEN BLACK-OUT AND UNCONSCIOUSNESS



onset of the 80 degree light loss to the onset of unconsciousness was only 3.6 seconds (Figure 4). Stauffer demonstrated that the time from 23 degree peripheral light loss to unconsciousness was 3.2 seconds (5). Our data also demonstrate the short interval of time from onset of visual symptoms to the onset of unconsciousness, and demonstrate that peripheral light loss, even when the light stimulus is extended far into the peripheral fields, has limited usefulness as an early indicator for the onset of unconsciousness because of the short time period between occurrence of these two symptoms in most subjects.

The mean duration of unconsciousness and recovery of cerebral function of sufficient degree so that the subject is able to respond to appropriate visual or auditory stimuli was 13.92 seconds with a range of 4.8 to 37.3 seconds. Of course as soon as unconsciousness occurred, the superstructure was immediately decelerated. No attempt was made for detailed comparison of our data with data from other laboratories because there has been no basic standardization regarding the conditions used in human centrifugation throughout the world (6). It is necessary and imperative that basic standards be established for centrifuges throughout the world.

CONCLUSIONS

These experiments were designed to determine the relationship between peripheral light loss at 80 degrees and blackout and unconsciousness in regard to G spread and time spread. Normative data have been presented.

In human centrifugation, it is believed that consideration should be given to the use of an 80 degree light located in the peripheral fields as an early indicator of peripheral light loss. In almost every case of our original 115 subjects, the subject lost his 80 degree light prior to the 23 degree lights under conditions of the experiment. When quantitated in a different group of 30 subjects (52 series), the 80 degree light represents an earlier indicator by a mean of 0.3 G for greyout than the standard centrifuge dashboard lights as presently used at Pensacola.

The peripheral light loss in itself has limited usefulness as an early indicator for the onset of unconsciousness because of the short period between the two symptoms. Pilots should be indoctrinated to be careful in relying on peripheral light loss or greying as an early indication for the onset of blackout or unconsciousness while performing aerobatic maneuvers involving positive radial G force.

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